

But What Will It Cost? The Evolution of NASA Cost Estimating

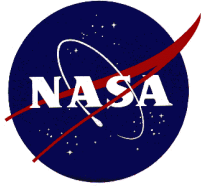
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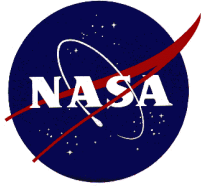
**Presented at Space Systems Cost Analysis Group
June 1994 Meeting in Toulouse France**

**Presented at 2000 NASA Cost Estimating Symposium
March 2000 Jet Propulsion Laboratory**



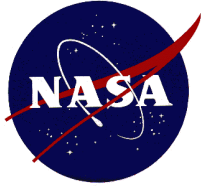
The Origins Of The Art

- **World War II cost estimating based on labor and material build-up**
- **Only statistical tool in use was learning curve based on 1936 work by T.P. Wright**
- **In the late 1940's the Department of Defense/Air Force was beginning to study future jets, missiles and rockets**
- **Needed responsive cost estimating methods for RDT&E and first unit costs**



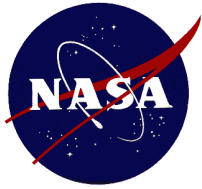
Early Rand Work

- In the late 1940's, the Air Force established the Rand Corporation for independent analyses
- Rand cost analysis department established in 1950 under David Novick
- Rand developed CER as basic estimating tool
- By 1951 Rand was devising aircraft CERs based on speed, range, altitude, etc.
- CERs were soon being stratified by fighters, bombers, cargo aircraft etc.
- Methods were extended and improved upon throughout the 1950's



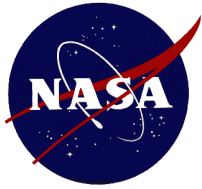
The Origins Of NASA

- **In 1957 the Army von Braun team in Huntsville Alabama was studying large rocket boosters**
- **Inspired by Rand success, rocket CERs were devised**
 - Data base pieced together from experimental rockets
 - Gross lift-off weight used as independent variable
- **Soviet Sputnik launch in the fall of 1957 greatly increased emphasis on a new large booster**



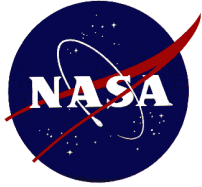
The Birth of NASA

- **NASA chartered in 1958 and absorbed several existing organizations including**
 - Langley Research Center in Virginia
 - Ames Research Center in California
 - Lewis Research Center in Ohio
 - Army Ballistic Missile Agency in Alabama (including von Braun team)
 - Department of Defense Advanced Research Projects Agency
- **NASA inherited the engineering and management practices of the above organizations, including their cost estimating methods**



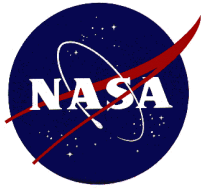
The Early NASA Years

- **NASA's first 10-year plan submitted to Congress in 1960 calling for**
 - Earth orbital satellites
 - Lunar and planetary probes
 - Larger launch vehicles
 - Manned flights to earth orbit and around the moon
 - Cost estimates assembled from analogies, intuition and guess-work
- **Soviets orbited Yuri Gagarin in April of 1961**
- **NASA Administrator Jim Webb asked to provide Congress and President Kennedy with a manned moon project**
 - Webb had been briefed on a \$10 billion project
 - He prudently decided to quote a \$20 to \$40 billion range



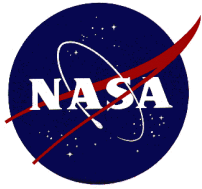
The Early NASA Years (cont'd)

- **President Kennedy, in his May 1961 State of the Union address, established the goal of a manned lunar mission before the end of the decade**
- **NASA quickly organized itself for the effort**
 - Marshall Space Flight Center (MSFC) in Huntsville Alabama took responsibility for Saturn launch vehicles
 - The new Manned Space Center (MSC) in Houston Texas was given responsibility for the crew modules
 - The Jet Propulsion Laboratory (JPL), having already developed the Explorer satellite, was given the lead for planetary programs
 - Goddard Space Flight Center (GSFC) was assigned unmanned Earth orbital missions



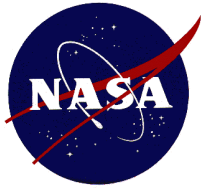
The Early NASA Years (cont'd)

- **As planning proceeded between 1961-65, NASA utilized several costing approaches**
 - Contractor estimates (largely labor and material build-up)
 - MSFC 1960 *Economy of Space Flight* by Herman Koelle and Bill Huber
 - 1961 *Handbook of Astronautical Engineering* by Koelle
 - The Air Force 1965 *Space Planners Guide* which included a chapter on weight based CERs
- **Planning Research Corporation (PRC) was contracted by JPL's Bill Ruhland in 1967 to improve the CERs of the Space Planner's Guide**
- **GSFC developed unmanned earth satellites costing approaches by a newly organized Cost Group (Bill Mecca, Paul Villone and Werner Gruhl)**



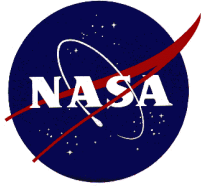
The Early NASA Years (cont'd)

- By 1965, NASA cost estimating was becoming a recognized discipline as opposed to relying on design engineers
- Design engineers lacked the necessary interests, skills and resources for costing
- Parametric cost estimating approach was on the ascent
- Rapidity of NASA project planning, contractor bids required dedicated estimators
- Cost review process was being established which called for estimates based on historical actuals



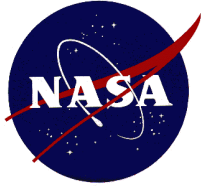
The Early NASA Years (cont'd)

- **1964-1965 was a regrouping time**
- **Cost estimating function embedded within advanced mission planning organizations at both MSC (under Max Faget) and MSFC (under Herman Koelle)**
- **MSFC contracted with Lockheed and General Dynamics for life cycle cost model for launch vehicles (led by Terry Sharpe of MSFC)**
- **MSFC parametric cost group taken over by Bill Rutledge**
 - Initiated REDSTAR data base
- **MSFC labor and material estimating group headed by Rod Stewart**
 - Later to author of numerous cost estimating books
- **MSC estimating headed by Dr. Humbolt Mandell**
 - Later to play leading roles in Shuttle and Space Station



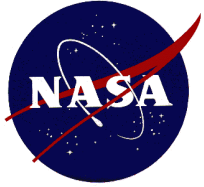
The Early NASA Years (cont'd)

- **Computational tool evolution**
 - 1960-65: Freidan mechanical calculators
 - 1965-70: Fortran cost models on mainframes
 - 1970-75: Four function handheld electronic calculators
 - 1975-80: Programmable handheld electronic calculators and first microcomputers
 - 1980-85: Apple II's and IBM PC's; first spreadsheets including Visicalc, Supercalc and Lotus 123
 - 1985-1990: Mac's and Windows PC's; mature spreadsheets
 - 1990-current: Mac's and Window PC's; more sophisticated applications (e.g. Excel macro apps)



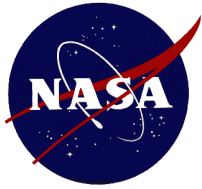
The Early NASA Years (cont'd)

- By 1967 MSC and MSFC were beginning to obtain the first historical data from the Apollo Program
- Saturn 1B and Saturn V
- Command and Service Module
- Lunar Excursion Module
- Results documented in 1969 “Apollo Cost Study”
- Where the typical CER had included two or three data points, it could now be “improved” to include four or five data points



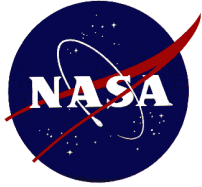
The Shuttle Era: Promise Of Low Cost

- **While the July 1969 Apollo 11 mission to the moon was still two years away, the 1968 NASA budget mark was less than 1967**
- **Future planning activities were scaled back from space stations and Mars missions to a new focus of low earth orbit access**
- **March 1969 Task Force report recommended development of a space shuttle system**



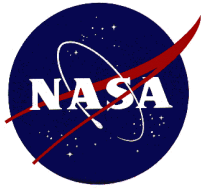
The Shuttle Era: Promise Of Low Cost

- **Inhouse and contracted Shuttle Phase A studies performed in 1969**
 - Projected \$10 billion development cost
 - Operating cost of a few million per flight
- **Cost reviews in late 1969 uncovered several problems**
 - OMB was forecasting continued NASA budget reductions
 - Shuttle cost estimates lacked credible analogous data (no previous winged reusable spacecraft)
 - Multitude of configuration options had overloaded NASA estimating staffs
 - Yet cost was one of the most key variables in the shuttle decision making process



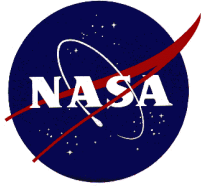
The Shuttle Era: Promise Of Low Cost

- **In mid-1970 NASA proceeded in the Shuttle Phase B studies**
 - Studies completed in the summer of 1971
 - However, the Shuttle cost estimates and the OMB NASA budget projections were seriously mismatched
 - *And* OMB was asking for an economic justification of the Shuttle
- **Shuttle Cost trade-offs**
 - Reusable interior tanks scrapped for expendable tank
 - Reusable flyback booster scrapped for expendable liquid boosters, then expendable solid boosters
 - Resulting design met (barely) OMB development cost guidelines (\$5.2 billion)
 - Cost per flight increased substantially



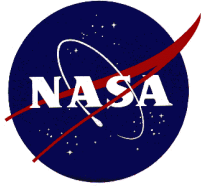
The Shuttle Era: Promise Of Low Cost

- Shuttle economic justification required skills which NASA did not have inhouse
- NASA hired “independent” help: Aerospace Corporation, Lockheed and Mathematica (Oskar Morgenstern and Klaus Heiss)
- Resulting conclusions were that Shuttle was economic compared to expendable launchers
- Aerospace projected a requirement for 60 Shuttle flights per year
- Mathematica did discounted cost-benefits
- Lockheed predicted 40% savings in satellite costs
 - Less lightweighting and miniaturization of satellites
 - Satellite retrieval and reuse
 - Satellite standardization around Shuttle interface



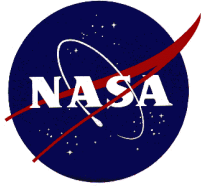
The Shuttle Era: Promise Of Low Cost

- **In 1972 President Nixon endorsed Shuttle and contract was let to North American**
- **Debate of Shuttle worthiness raged on**
- **All through 1973, NASA cost analysts were busy with extensive “capture/cost” exercises to produce data to answer Congressional, OMB and GAO cost questions**
- **Final Shuttle economic story projected economic attractiveness**
 - \$14 billion (1972 dollars) in savings over 12 years
 - 19% internal rate of return(real)
 - Based on a Shuttle DDT&E cost of \$5.2 billion (1972\$)
 - Based on 60 flights per year
 - Based on a Shuttle cost per flight of \$10 million (1972\$)



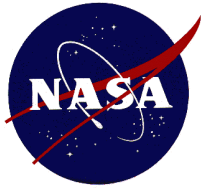
Declining Budgets, Rising Costs

- **As NASA's budget declined in the 1970's, JPL and GSFC pioneered cost saving techniques such as protoflighting and increased use of off-the-shelf hardware**
- **NASA Headquarters strengthened its cost analysis oversight capabilities under Mal Peterson and Werner Gruhl**
 - Championed improved data and estimating
 - Instituted regular NASA Cost Estimating Symposium
 - Instituted the Non-Advocate Review (NAR)



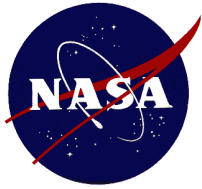
Declining Budgets, Rising Costs

- **PRICE Model marketed in 1975**
- **First developed as internal RCA model by Frank Freiman**
- **Freiman modeled cost using logical relationships between a rich set of key variables**
- **Model could be calibrated to organizations**
- **During Shuttle Phase B's, RCA impressed NASA management with the PRICE model's capabilities**
- **NASA provided RCA with a data base of historical cost information and encouraged Freiman to market his invention**



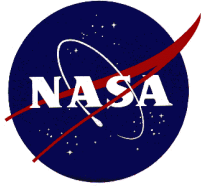
Declining Budgets, Rising Costs

- During 1970's and mid-1980's, despite better tools and review processes, NASA cost continued to rise and overruns worsened
- At Headquarters, studies by Werner Gruhl and at JSC, studies by Hum Mandell, Richard Whitlock and Kelly Cyr concluded that NASA culture and increasing complexity were the primary drivers
- Despite these findings, NASA culture remained fixed and complexity of missions continued to rise



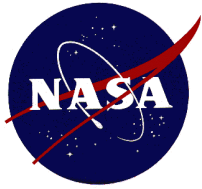
Recent Years

- **Once Shuttle was flying, NASA turned its attention to Space Station**
- **Pre-Phase A and Phase A studies conducted**
- **In 1983 Configuration Development Group was appointed to lead the Phase B's**
 - O'Keefe Sullivan from MSFC named lead estimator
 - Sullivan had just completed managing PRC development of the Space Station Cost Model
 - Model combined data from Shuttle Orbiter, Apollo modules, Skylab and other sources
 - Model provided to all Centers as standard tool
 - Sullivan estimate was \$11.8 to \$14 billion (1984 \$)
 - NASA Administrator Jim Beggs, under pressure to propose something affordable, committed to Congress in September of 1983 to build the Station for \$8 billion



Recent Years

- **NASA pushed ahead with Station Phase B**
- **In the fall of 1987 the Critical Evaluation Task Force was organized to narrow the options**
 - Bill Rutlege led team of NASA estimators (Bill Hicks, Richard Whitlock, Tom LaCroix and Dave Bates)
 - The new Station baseline design was estimated at \$14 billion, which was submitted to OMB
- **Amid great political debate, the Station program was given a go-ahead**
- **Continued budget woes have forced redesigns and “close votes” in Congress**
- **Today, the Station program is implementing the final(?) redesign (including Russians)**
- **\$2.1 billion annual budget “agreement” with Congress is under attack (Summer of 1994)**



Voices from the Past

Names are NASA civil service individuals who formerly performed as cost analysts. Cost analyst is defined as a parametric or “grass roots” cost analyst, estimator or modeler. It does not include financial or program control analyst. The list also excludes contractor cost analysts, as well as current civil service cost analysts.

MSFC

Bill Huber
Terry Sharpe
Bill Rutledge
Walt Wood
O’Keefe Sullivan
Murray Castleman
Bob Rutherford
Herb Vaughan
Dave Taylor
Spencer Glasgow
Jerry Wheeler
Don Bishop
Dick Klan
Sam Sullins
Bill Hicks
Glenn Dodd
Steve Creech
Saroj Patel
Jack Housley
Rod Stewart
Keith Smith

Julie Martz

Cary Thompson
Allen Forney
Lowell Smith
George Mahoney
Cynthia Fry
Bill Powell

KSC

Geroge Mosakowski
Walter Feitshans
Nick Talluto
Chris Winewicz
Joe Brown (C of F)

GSFC

Bill Mecca
Paul Villone
Werner Gruhl
Bernie Dixson
Don Strobe

Mary Anne Gallagher
Jerry Gonzales

JSC

Hum Mandell
Gil Chisholm
Richard Whitlock
Howard Ashley
Wayne Draper
Wayne Whittington
Howard Renfro
Ralph Shomberg
Richard Fox
Phil Shanahan
Jim Wilcox

LeRC

George Novack
Marie Cassidy
Chris Beins
Tom LaCroix

NASA HQ

Tom Campbell
Mike Mann
Frank Rosenberg
Charlie Tulip
Mal Peterson
Jo Gunderson
Dave Bates
Kristen Erickson
Logan Doane
Lisa Guerra
Andrew Hunter
Tony Schoenfelder
Tony Diamond
Henry Hertzfeld

JPL

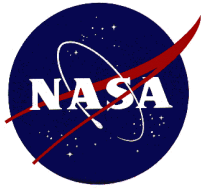
Bill Ruhland
Stu Heller
Helmut Partma
Jerry Olivieri
Jeff Smith

LaRC

Joe Twigg
ED Deam

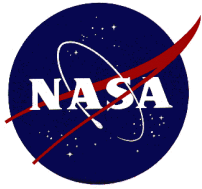
ARC

Chuch Jackson
Sylvia Cox



Concluding Observations

- **NASA cost estimators have played a crucial role in every major historical program**
- **This active participation continues unabated**
- **Administrator has called for improved cost effectiveness**
- **A new “NASA Management Instruction” implements this vision**
- **The NASA cost estimating community is preparing to deal with a new culture**
 - Total Quality Management
 - Concurrent Engineering
 - Use of matured technology
- **NASA estimators will continue to be asked: “But What Will It Cost?”**



Suggestions For Bringing History Up To Date (from 1994 to 2000)

- **Dan Goldin era**
 - Faster, better cheaper
- **Space Station continued cost growth**
- **Continued space transportation studies**
 - Augmented with X vehicles and ground technology programs
- **Continued Human Mars Mission studies**
- **Product development teams and concurrent engineering centers**
- **Expansion of cost analysis role to include financial analysis of commercial ventures, cost benefit analyses, etc.**
- **Agency downsizing and its effect on cost estimating offices**
- **Improved tools**
 - Inhouse models (NAFCOM, Aerospace Smallsat model, etc.)
 - Commercial models (Price, Seer, MS Project, @Risk, etc.)
- **Inter-agency cooperation (NASA, Air Force, Navy, Army, CIA, NRO, ESA)**
- **Parametric Estimating Initiative**
- **Advent of the Independent Program Assessment Office (IPAO) and the Systems Management Offices**
- **Rethinking faster, better, cheaper in 2000**